Near-field Measurements on Antennas with internal LO

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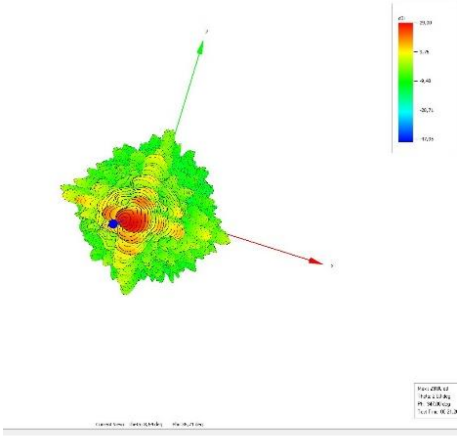
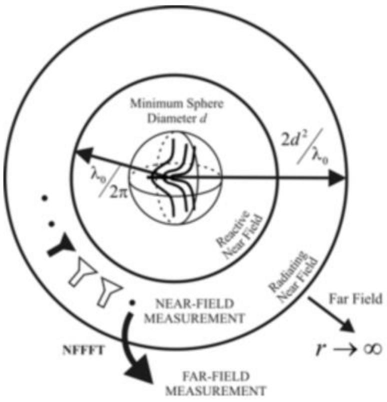


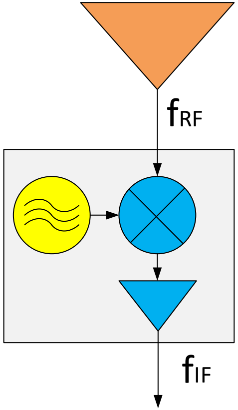
Antenna Measurements

- Antenna pattern is characterized by far-field radiation pattern
- Far-field valid for distances > $2d^2/\lambda$
  - D: diameter of minimum sphere enclosing the antenna under test (AUT)
  - λ: wavelength
- Requires huge anechoic chambers
- Near-field far-field transformation
  - Reduces the size of test chamber
  - Requires magnitude and phase information



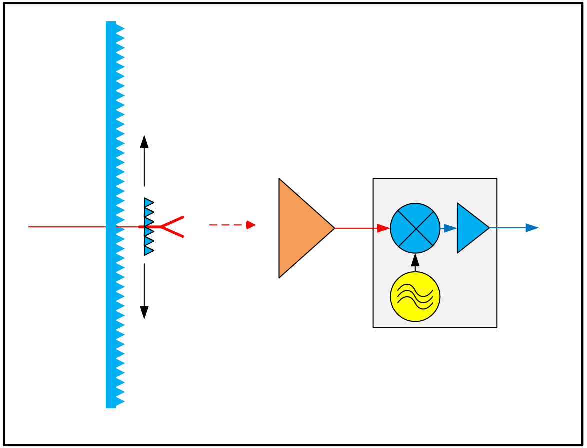
AUT: Antenna with integrated Frequency Converter

- Antenna with integrated receiver
- Internal LO
- LO not accessible
- Reference frequency not available
- Phase of output signal (f IF) changes with change of phase of DUT and phase of LO



Typical Test Setup (Planar Scanner)

- Antenna scanner with movable antenna
- Movement of the scanner, not the AUT
- Normalization to boresight
- Measurement of magnitude and phase of the output signal in respect to boresight



- Typical Test Setup
  - Stimulation by VNA or ext. source
  - Measurement of a reference-input and a measurement-output signal

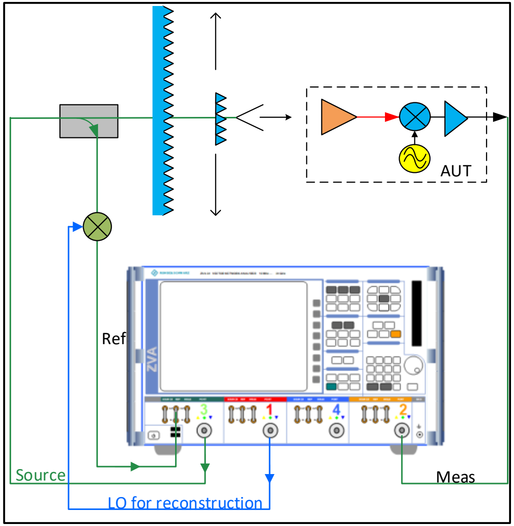
Test Setup for AUT with internal Local Oscillator

- Measurement of magnitude works
- Phase depends on synchronization between internal LO and sources of ZVA

- Phase synchronization requires access to the LO or high frequency reference frequency

- Without LO access phase measurement becomes instable especially for long measurement times

- Other techniques as „LO reconstruction“ will fail

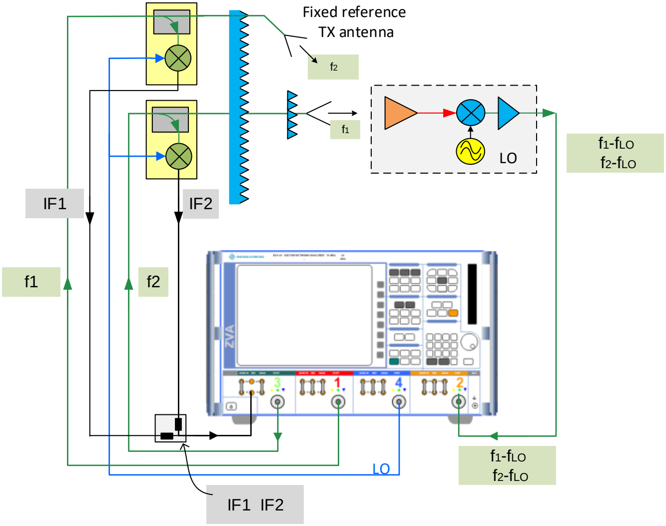


Solution: Phase Measurement using the 2-Tone Technique

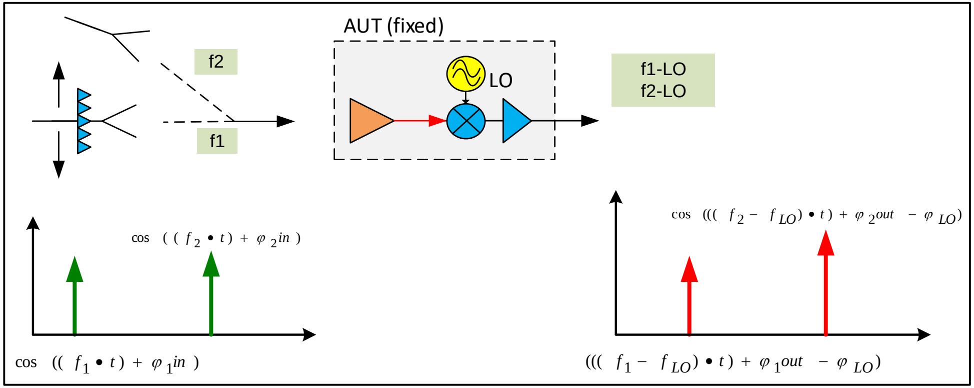
- Add second Reference Tx-Antenna in fixed position
- Reference antenna transmits f2 with offset Δf in respect to stimulus (scanner) antenna (f1)

- AUT receives simultaneously
  - TX measurement signal f1
  - TX reference signal   f2=f1+Δf
  - Down converts both signal to f1-fLO and f2-fLO

- ZVA measures
  - Down converted stimulus signals IF1 and IF2
  - AUT signals f1-fLO and f2-fLO

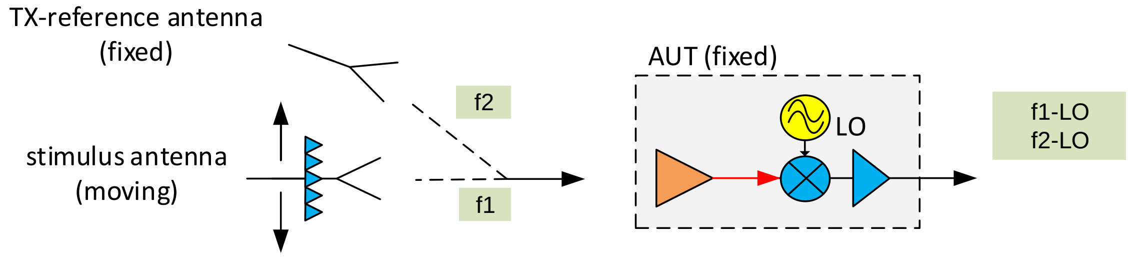


Elimination of the LO Phase using the 2-tone Technique



- Δφ = (φ1out-φLO-φ2out+φLO) - (φ1in-φ2in) = (φ1out-φ2out) - (φ1in-φ2in)
- The difference of φ1out and φ2out is independent of the LO phase
- LO phase and frequency changes are cancelled out

Phase Measurement of the Antenna

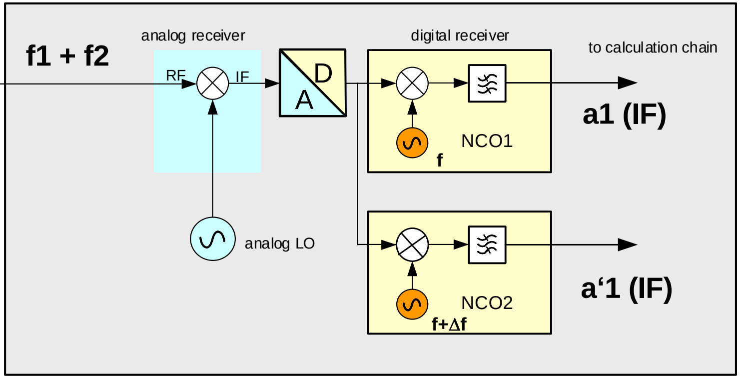


- Reference TX-antenna is fixed
- Antenna under test is fixed
- Stimulus antenna is moving

- $\Delta\varphi$ is the phase change due to the position change of the stimulus antenna

Phase Measurement of signals with different Frequencies using digital Dual Receiver Architecture of the ZVA - VNA

- Down conversion of both tones to the analog IF
- A/D conversion with 80 MHz sample rate
- Two separate IF chains with independent digital oscillators (NCO1 and NCO2)
- NCO1 and NCO2 with arbitrary offset
- Down conversion of two signals tones to IF=0
- Digital filtering of both signals in digital receiver
- Measurement and display e.g. as a1 and a1‘



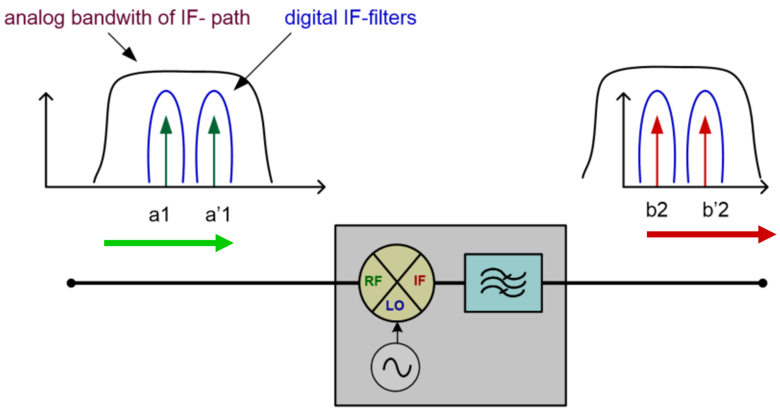
The Measurement of the Phase between Signals with different Frequencies

- Measurement of phase difference ϕ2in – ϕ1in of both input signals with dual receiver frontend of reference receiver of Port 1
  - Analog down conversion to IF (20 MHz) of f1 and f2 (=f1 +Δf)
  - Digital down conversion to IF (0 Hz) with numeric controlled oscillators (NCO), frequency offset between NCO1 and NCO2 = Δf
  - Detection of phase difference ϕ2in – ϕ1in

- Measurement of phase difference ϕ2out – ϕ1out of both output signals with dual receiver frontend of Port 2

- Calculation of the phase difference of the “phase differences”
- $\Delta\varphi = (\varphi_1\text{out}-\varphi_2\text{out}) - (\varphi_1\text{in}-\varphi_2\text{in})$

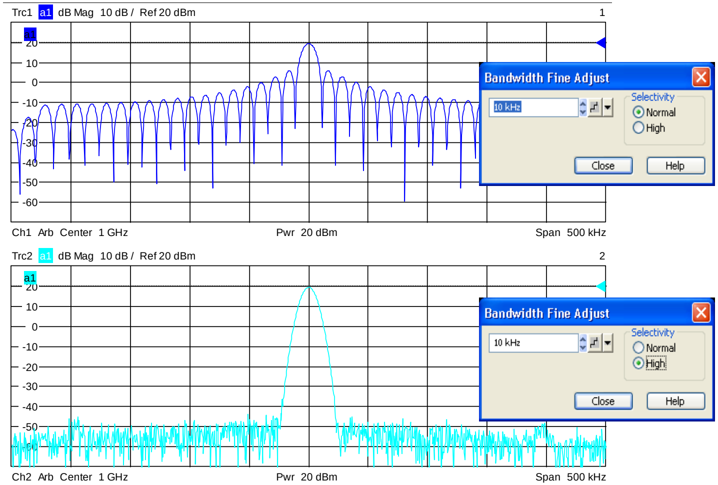
The Measurement of the Phase between Signals with different Frequencies



High selective digital Filters

- Typical VNA IF-filters are designed for fast settling and measurement of single CW signals
- High sidelobes may cause interference for two tones especially with small offset

- Solution:
  - High selective digital IF filters
  - High shape factor
  - >70 dB stopband attenuation

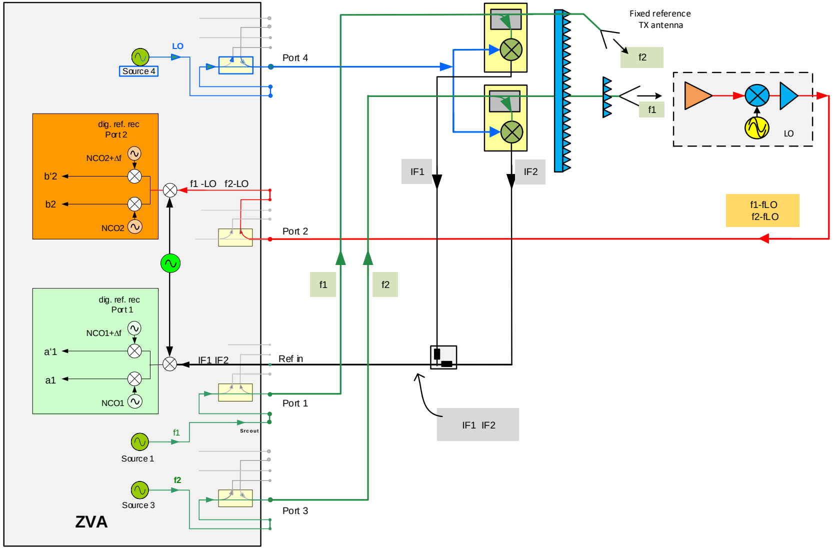


Test Hardware Setup

- 4-source VNA
- Generates both stimulus tones
- Generates the external LO

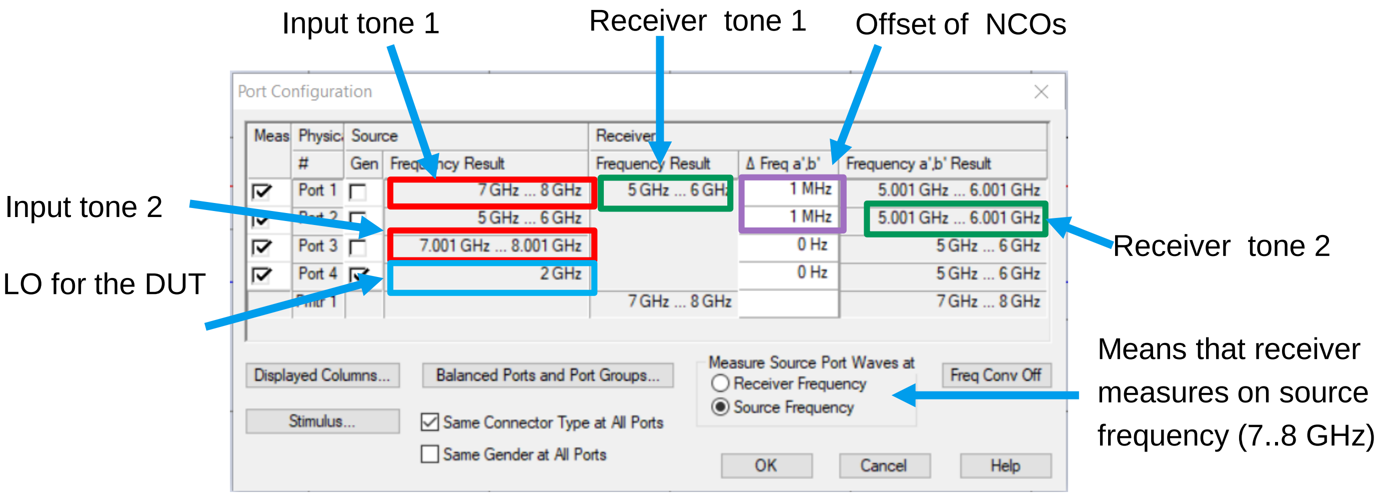
- Measures the ratios:
  - a1/a‘1
  - b2/b‘2

- DUT−Phase $= \dfrac{a1/a'1}{b2/b'2}$



The Instrument Setup

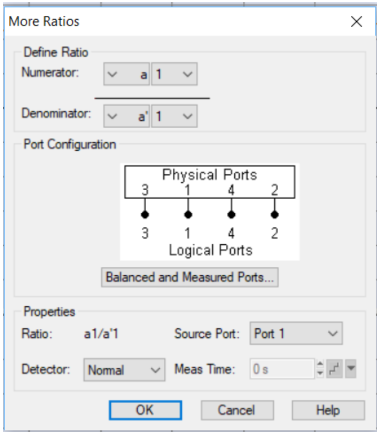
The settings for the generators and the receivers



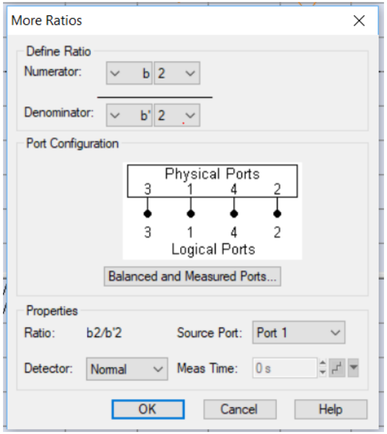
Instrument Setup

The Measurement of the Input and the Output Signals

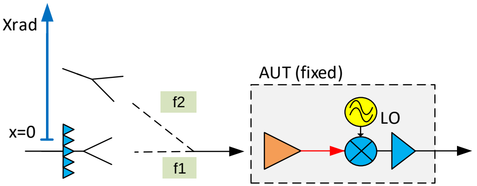
Input Signals (Trace 5 Trc5)



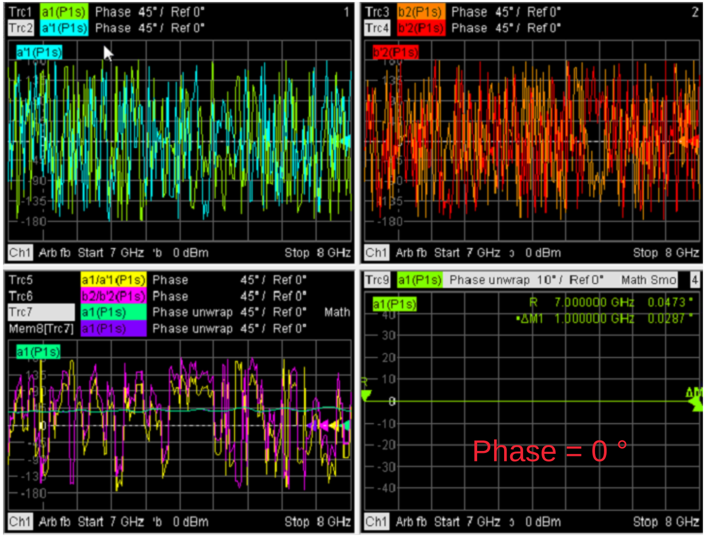
Output Signals (Trace 6 Trc6)



Measurement Technique and Procedure

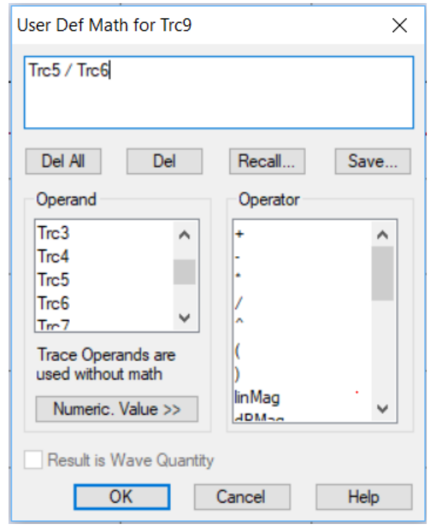


Calibration at position x= 0m

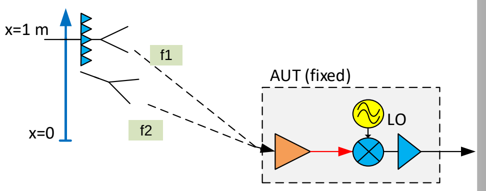


Calculation of the „Ratio of the Ratios“

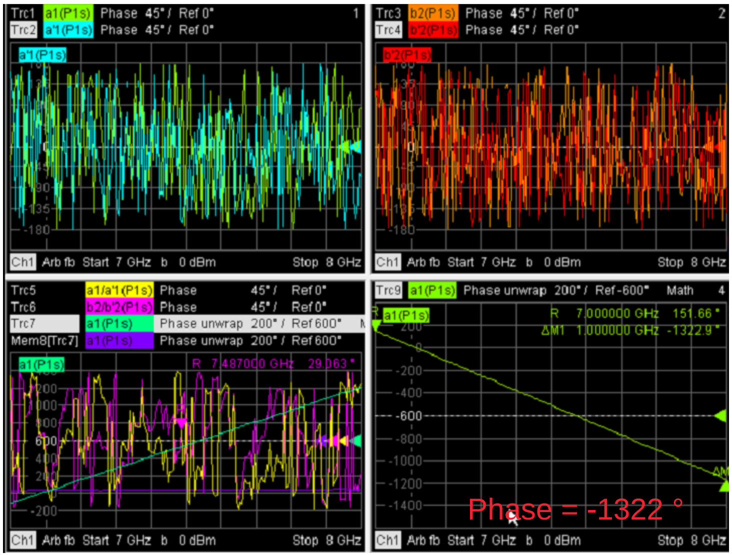
- Calculation of the ratio using trace math
- Provides magnitude and phase
- Calculation in real time



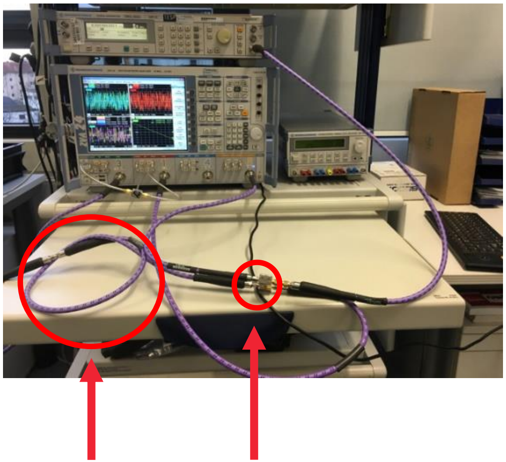
Measurement technique and procedure



Calibration at position x= 1m



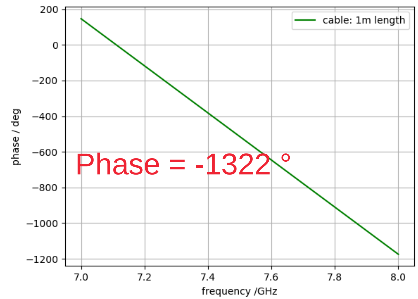
Proof of Concept

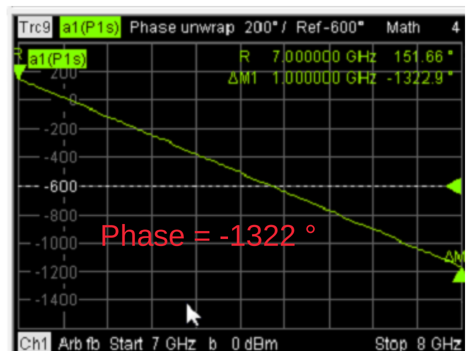


1 m cable

Two antennas and mixers

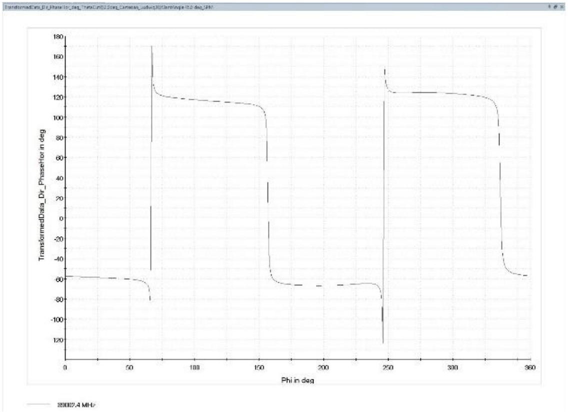
Calculated phase



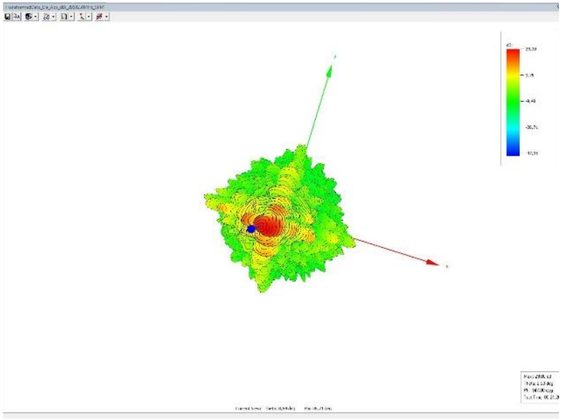


Measurement of a 5G active massive MIMO Antenna

Phase Cuts



After NFFF Transformation



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